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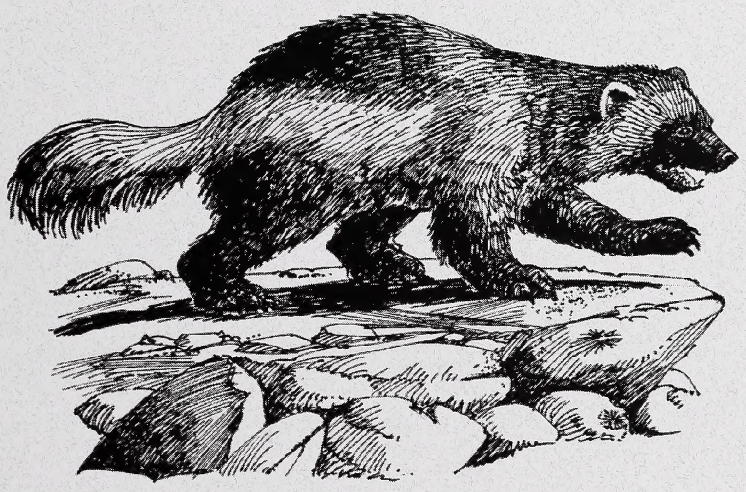
Measuring Wolverine Distribution and Abundance in Alberta



Alberta Species at Risk Report No. 32

Alberta
SUSTAINABLE RESOURCE DEVELOPMENT

Measuring Wolverine Distribution and Abundance in Alberta

Garth Mowat

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EXECUTIVE SUMMARY

Recent and continued expansion of industrial activity has led to widespread habitat loss, habitat alteration and disturbance for forest carnivores (Ruggiero et al. 1994). In Alberta, concern from trappers and the scientific community suggests that both the distribution and abundance of wolverine (Petersen 1997) may be declining. An objective method for monitoring wolverine distribution and estimating abundance would allow informed conservation decisions.

I reviewed the methods available for inventory of wolverine. Snow tracking in systematic cells could be used to monitor distribution of wolverine, though power to detect a population decline is likely to be low. An aerial track survey method tested in open forest in Alaska may work to estimate wolverine population size in the very northernmost forests of Alberta. I suggest hair sampling combined with microsatellite genotyping, though still in the testing phase, is likely to be the most valuable method to measure both abundance and distribution of wolverine. Study designs to measure distribution are similar to those for estimating population size and it may be most sensible to test designs that emphasize both objectives, at least initially.

Several methods need testing before hair sampling could be used to estimate wolverine abundance. We must develop an efficient method to remove hair from wolverine in the wild. During prototype testing we need to estimate capture success (per trapnight) for wolverines in several areas of Alberta. This information will allow more precise study design and budget forecasting when a full scale inventory is attempted. We need an automated species test to allow cost effective and objective species assignment of samples. We must select a suite of microsatellite markers that give us maximum power to identify individuals using hair samples. A workplan is presented for achieving the above goals.

1.0 INTRODUCTION

Recent and continued expansion of industrial activity such as forestry, oil/gas exploration and extraction, and agriculture has led to widespread habitat loss, habitat alteration and disturbance for forest carnivores (Ruggiero et al. 1994). In Alberta, concern from trappers and the scientific community suggests that both the distribution and abundance of wolverine (Petersen 1997), and perhaps fisher, lynx and otter, may be declining. Given these conservation concerns an objective method of estimating population distribution, trend and perhaps abundance would greatly aid conservation efforts. Recently developed hair sampling and genetic analysis techniques may offer a feasible means of monitoring wolverine abundance in forested environments though testing and adaptation of specific methods is needed before a standardized methodology is possible.

2.0 OBJECTIVES

The objectives of this report are to:

1. Review the current literature on estimating population trend and size for wolverines.
2. Review the current state of knowledge on the use of hair capture and DNA analysis for medium sized furbearers.
3. Suggest which method, or combination of methods, is most likely to be successful for estimating population trend and/or size for wolverine in boreal forest environments.

3.0 METHODS

I review published and unpublished literature on estimation of wolverine population size in order to make recommendations regarding estimating population size and monitoring trend for wolverine in Alberta. It became apparent that a DNA based method was likely to be most suitable for the large areas of interest here hence, I also reviewed methods for hair capture for wolverine and other similar species based on scientific publications, unpublished information, and direct communications with biologists currently working in that field. I used this information to make detailed recommendations about developing a wolverine inventory methodology. I highlight steps that involve the greatest risk of failure and offer alternatives should the preferred method turn out not to be feasible. I have tried to give special consideration to methods that may also sample fisher, otter and lynx at the same time.

4.0 RESULTS

Estimating population size for wolverines is problematic because of their scattered distribution and low population densities. Sample surveys are difficult because they are destined to have low sample sizes. Census based methods are also difficult because the large home range size of wolverines means observers have to cover large areas to encircle a population of animals. Table 1 presents densities for wolverine from various parts of North America and Scandinavia. The details of each method used and several more recent methods are discussed below with special reference to the monitoring of wolverine abundance in the boreal forest environments typical of northern Alberta. See Table 2 for a summary of possible inventory methods.

Table 1. Wolverine densities from selected North American studies.

Density (/1000 km^2)	Trapnights/ capture[a]	Study Area Size (km^2)	Location	Methods	Author
5.1-6.4	~37	4000	SE British Columbia	live capture/photo traplines	Krebs et al. 2000
5.4-6.6	27-71	8900	NE British Columbia	live capture/photo traplines	E. Lofroth, pers. com.
15.4		1300	Montana	live-capture/telemetry/ track counts	Hornocker and Hash 1981
4-11.1	36-47	8000	Idaho	as above	Copeland (1995)
20.8		2400	Alaska-foothills	as above	Magoun 1985
7.2		about 5000	Alaska-foothills and coastal plain	as above	Magoun 1985
10.8		1800	southern Yukon	live-capture and telemetry assuming exclusive home ranges	Banci and Harestad 1990
4.8		51,200	northeast BC	snow tracking and harvests	Quick 1953
5.2±20% (95% CI)		1870	Alaska	tracking and probability estimator	Becker 1991
2.8-3.6		≈13,000	Central Norway	Extrapolations from den surveys	Landa et al. (1998)

[a]Capture success is likely to be somewhat lower with DNA traps as these numbers include recaptures of the same individuals over short time frames. This data would be combined into one session in a mark-recapture scenario. Also, the workers used large unprotected baits that rewarded trapped individuals and hence they may have achieved greater recapture success than would be expected in a hair capture scenario, especially if animals are not rewarded.

Radiotelemetry and Snow Tracking: This is commonly done by intensive live-trapping, radiotelemetry, and snow tracking. Live capture results provide the minimum figure to estimate the minimum number alive (MNA), and snow tracking in conjunction with radio locations provide a means to test for individuals that were not captured. Radiotelemetry locations are also used to assess residency status on the study area. Researchers also commonly infer certain animals were not captured by home range analysis of radio locations (post hoc). Areas in which there are no locations may have a resident animal that was not captured. Sometimes researchers assume that female home ranges do not overlap, and ascribe the mean home range size for a given sex to the uncaptured individuals. Some researchers correct for animals living partly or entirely off the study area to reduce 'edge effect' using subjective criteria. White et al. 1982, Bondrup-Nielsen (1983), Boutin (1984), and Garshelis (1992) have all demonstrated that this error can cause significant overestimates of population size. Garshelis (1992) describes a method using mark-recapture of individuals weighted by their time spent on the study area. This method corrects for edge effect and estimates the number of animals not captured at the same time. At this time there is no specific closed or open form model for this estimator so there is no means to calculate confidence intervals, other than using those generated from the simple Petersen equation (Garshelis 1992). This method can overcome errors to do with edge effect, however, it will be constrained by minimum sample sizes necessary for mark-recapture studies (see section Mark-Recapture section). Some form of the radiotelemetry method has been used in most North American studies of wolverine, and for many other carnivores (Hornocker and Hash 1981, Magoun 1985, Banci and Harestad 1990).

Assumptions: 1) all resident animals are captured (including young of the year and transients or these cohorts are listed as excluded); if all residents are not captured, then snow tracking (or post hoc home range analysis methods) is of sufficient effort to detect all individuals that were not captured, 2) radio locations accurately classify residency status, 3) in some cases researchers are assuming female home ranges do not overlap significantly.

Limitations: 1) there is considerable subjectivity involved in such decisions as deciding on residency status, cross boundary movement, how many individuals were not captured, age classes to exclude from estimate, 2) it requires intense effort and therefore it is not feasible for broad based inventories, 3) there is no estimate of precision [there is a general estimate of precision with the method of Garshelis (1992)], 4) often young of the year or transients are left out of the estimate which gives a lower estimate than the 'trappable population'.

Benefits: 1) this method can provide accurate estimates of population size if effort is sufficient, 2) provides data on many other aspects of biology, 3) offers an objective method of correcting for edge effect.

Table 2. Summary of possible methods for estimating wolverine population size or density.

Method	References
1. Radiotelemetry and snow tracking	Hornocker and Hash 1981, Magoun 1985, Banci 1987, Garshelis 1992
2. Snow Tracking	Quick 1953, Haglund 1966, and perhaps Pullianen 1963
3. Probability Sampling and following tracks	Becker 1991
4. Probability Sampling and radiotelemetry	Becker 1991
5. Live-capture and aerial survey	Miller et al. 1997
6. Live-capture and photo trapline	E. Lofroth & J. Krebs, unpubl. data, Copeland 1993, Mace et al. 1994
7. Live capture and hair capture/DNA analysis	
8. Hair capture/DNA analysis	Woods et al. 1999
9. Radio isotope marking and recapture of scats	Conner and Labisky 1985
10. Radio isotope marking and recapture using hunter samples	Garshelis and Visser 1997
11. Extrapolations based on den surveys	Landa et al. 1998

Snow Tracking: Systematic snow tracking surveys can be used to measure the distribution of wolverine over relatively large areas. Transects need to be long enough to generate a reasonable probability of detection; counts can be repeated to reduce the variation in response among counts (Thompson et al. 1987). Given the large size of wolverine home ranges, track transects will probably need to be 10 km long or longer to generate a reasonable detection probabilities (Becker 1991). If track counts and trailing are intensive, researchers can estimate a MNA based on mapping of territories and their ability to separate individuals due to spatial separation. Some form of this method has been attempted by Quick 1953, Haglund 1966, and perhaps Pullianen 1963. However, even with considerable effort (nearly 1000 km of tracking) Haglund was unable to provide an estimate of population size.

Assumptions: 1) The observer is able to identify all individuals in the study area, 2) the observer does not include individuals that do not reside in the study area.

Limitations: 1) This technique requires extremely intensive effort and could only be accomplished effectively over relatively small areas, 2) there is no estimate of precision.

Benefits: 1) probably less expensive than method 1, but very labour intensive.

Den counts have been used to estimate population size in Scandinavia. The total number of dens is considered a partial estimate of breeding females in the population. Total female numbers was estimated based on the proportion of females denning in each year in 3 Scandinavian research projects (Landa et al. 1998). Population size is inferred by using sex and age ratios observed in intensively studied populations and long term harvest records (Landa et al. 1998). This method has been used in areas where human search effort is intense. Incentives are provided to livestock owners to search for dens and all dens are verified by a local wildlife official. This method is unlikely to be possible in Canada where human use of the landscape in winter is light and much of the potential distribution of wolverines is inaccessible. Massive field effort would be required to achieve an estimate for a study area of even modest size.

4.2 Probability Sampling

Becker (1991) and Becker et al. (1998) have developed three models that estimate population density based on movement distances of individual animals. Becker (1991) suggests using snow tracking along transects to count individual tracks deposited after the most recent snowfall. He then suggests following all tracks forward and back to measure the individuals movement since the snowfall occurred, or alternately to use radio telemetry to measure this distance. If the species is best detected using irregular flying patterns, such as concentric circles, then Becker et al. (1998) suggest using a stratified block approach such that observers can put varying levels of effort into each block in order to be certain they have identified all tracks present.

Becker's first method involves calculating an 'inclusion probability' (IP), essentially a sightability factor, for each track seen. The inclusion probability is the ratio of the distance travelled by the individual (perpendicular to the survey transects) and the distance surveyed, and is never greater than one. The less the individual moved after the snowfall, the smaller the IP. The population estimate is the sum of the inverse of the IP's. Hence the less an animal moves with respect to the total transect length the smaller the IP, and the greater the correction factor contributed by sighting that individual. These ideas can also be applied to blocks of habitat and, if there is prior knowledge about wolverine abundance, stratification can be used to increase precision. However, the transect method is likely to maximize detection for wolverine (Becker et al. 1998) and there are likely to be few instances where enough prior information about wolverine numbers exists to use stratification.

Assumptions: 1) All wolverine tracks crossed are seen and counted, 2) you must be able to follow all tracks to measure the individuals movement since the snowfall.

Limitations: 1) This technique can work only in areas where aerial or ground survey for tracks is feasible. Due to the large home range size and movement distances of wolverine only aerial survey is likely to be feasible. 2) Correct snow conditions can be limiting, 3) need high detectability of tracks for precision which is unlikely in most forest types in the Canadian provinces

Benefits: 1) can be done over large areas, 2) provides an estimate of precision, 3) accuracy can be checked by repetition, 4) reasonably cost effective, 5) works best for mobile species, such as wolverine.

Becker's second estimator is similar but it does not assume individuals can be snow tracked. The number of tracks crossing a transect is counted, and distance travelled by a sample of individuals is measured by following radiocollared animals. The population estimate is calculated by the ratio of total population movement to average individual movement.

Assumptions: 1) All wolverine tracks crossed are seen and counted, 2) the radiocollared sample provides accurate estimate of wolverine movements after snowfall, 3) the radiocollared sample accurately represents movements for all sex and age classes.

Limitations: 1) As with the previous method, this technique can work only in areas where aerial or ground survey for tracks is feasible. Due to the large home range size and movement distances of wolverine only aerial survey is likely to be feasible. Canopy closure of the forests in southern Canada is likely to be too dense to assure detection of all tracks crossed, 2) Correct snow conditions can be limiting, 3) a radiocollared sample of animals is needed, 4) spacing of transects must be large enough to assure that each track that is crossed is a different individual (this is tested in the previous model by tracking).

Benefits: 1) can be done over large areas, 2) provides an estimate of precision, 3) accuracy could be checked by repetition.

4.3 Mark-Recapture

Several configurations exist which may allow population estimation of wolverines using mark-recapture models. In intensively studied populations the live capture work could be treated as the capture session, and further recapture sessions could be provided by: further live-capture, aerial survey (aided by radio collars), photo traplines, or hair capture and subsequent microsatellite genotyping. Capture success during the recapture session would have to be high in order to make up for the relatively small number of animals initially marked. In populations not currently being studied aerial survey and photo trapline techniques would require a live capture session to mark a sample of individuals. Alternatively, hair capture/DNA analysis could be used to identify individuals for the mark and recapture sessions. Radio isotope marking could also be used for mark-recapture analysis.

In general, mark recapture estimators are difficult to apply to small populations such as wolverine because high capture success is required. Krebs (1989) suggests mark-recapture estimators are often invalid if population size is less than 100, he suggests defaulting to a 'Minimum number alive' model in these cases. However, MNA models require catchability of >70% for reasonable accuracy which is unachievable for most species and, even then this model can result in severely biased estimates (Jolly and Dickson 1983). Further, the smaller the population the greater the bias due to uncertain or partial residency status, an error coined 'edge effect' (White et al. 1982). Realistically, mark recapture methods would work best for wolverine if the study area is large, study area boundaries provide some barrier to movement, the total population is >60, and catchability is >20% of the population size in each session, using 3 or more capture sessions.

Live-capture and aerial survey could be effective if a large percent (>40%) of the resident wolverines can be located from the air by their tracks in fresh snow. However, the track must be followed forward to the point that the animal is seen, or the observers are close enough to confirm whether the individual is radiocollared (visually or using radio telemetry). Miller et al. (1997) present a method of estimating bear population size using radiocollaring for marking and aerial survey for recapture. Garshelis (1992) tried aerial surveys for bears in Minnesota and was unable to observe any bears in a 94 km^2 area known to contain at least 20 bears. Sightability of both tracks and animals is likely to be very low in southern boreal forests and only a small portion of the population is likely to be found above treeline on a given day.

> **Assumptions:** 1) The most important assumption for wolverine may be the assumption of population closure, which White et al. (1982) term geographic closure. Essentially this assumption means that the ratio of marked to unmarked animals does not change between sessions. This assumption is violated if there is significant movement of individuals on and off the study area between trapping sessions. This assumption is minimized by selecting study area boundaries that physically enclose animals on the study area. A significant positive bias can result if many animals are only partial residents. This problem is minimized when average home range size is small compared to the size of the study area (White et al. 1982). 2) All animals have equal catchability. This is virtually impossible however, Miller et al. (1997) felt that this bias was minimal because they marked bears over multiple years and used a different recapture technique. 3) Individuals must be positively identified during the capture and aerial survey.
>
> **Limitations**: 1) Requires live capture and radio collaring, 2) sightability of wolverine may be limiting, especially for the aerial track survey, 3) cooperative weather and snow conditions may be limiting.
>
> **Benefits**: 1) can be done over large areas, 2) provides an estimate of precision.

Live-capture and remote photography could be effective if a large portion of the wolverine population can be photographed, and if these individuals can be positively identified as marked or not. E. Lofroth (pers. comm.), D. Reid, and others photographed wolverine in northern B.C. during three winters. They found little difficulty in identifying marked from unmarked animals; their collared animals also had a coloured eartag in each ear (W. Harrower and C. Hoodicoff, unpubl. data). Recapture rates were highly variable possibly due to low sample sizes. Copeland (1993) tested the use of cameras to photograph wolverine on a study area with marked individuals and felt cameras were a useful method of gaining information about individual animals. He had few problems identifying individuals in photos (J. Copeland, pers. com.). Mace et al. (1994) used live-capture and subsequent photography to estimate grizzly bear population size in Montana; they recounted some difficulties in identifying marked animals from photos.

Assumptions: 1) The most important assumption for wolverine may be the assumption of population closure, which White et al. (1982) term geographic closure. Essentially this assumption means that the ratio of marked to unmarked animals does not change between sessions. This assumption is violated if there is significant movement of individuals on and off the study area between trapping sessions. This assumption is minimized by selecting study area boundaries that physically enclose animals on the study area. A significant positive bias can result if many animals are only partial residents. This problem is minimized when average home range size is small compared to the size of the study area (White et al. 1982). 2) All animals have equal catchability. This is virtually impossible however, Miller et al. (1997) felt that this bias was minimal because they marked bears over multiple years and used a different recapture technique. 3) Marked individuals must be positively identified in photos.

Limitations: 1) Requires live capture and marking, 2) all recaptured animals can be identified from photos, 3) capture rate at photo stations may be limiting.

Benefits: 1) can be done over large areas, 2) provides an estimate of precision.

Live capture and hair capture/DNA analysis would be feasible if a technique can be developed that consistently captures hair from wolverine that visit a site (see Method 8).

Assumptions: 1) The most important assumption for wolverine may be the assumption of population closure, which White et al. (1982) term geographic closure. Essentially this assumption means that the ratio of marked to unmarked animals does not change between sessions. This assumption is violated if there is significant movement of individuals on and off the study area between trapping sessions. This assumption is minimized by selecting study area boundaries that physically enclose animals on the study area. A significant positive bias can result if many animals are only partial residents. This problem is minimized when average home range size is small compared to the size of the study area (White et al. 1982). 2) All animals have equal catchability. This is virtually impossible however, Miller et al. (1997) felt that this bias was minimal because they marked bears over multiple years and used a different recapture technique. 3) Individuals must be positively identified with DNA analysis.

Limitations: 1) Requires live capture and radiocollaring, 2) capture rate at hair stations may be limiting.

Benefits: 1) can be done over large areas, 2) provides an estimate of precision.

Hair capture/DNA analysis would be feasible if a technique can be developed that consistently captures hair from wolverine that visit a site (as for method 7). If this can be accomplished this technique could be used for the capture and recapture sessions, negating the need for live capture. This would make this technique much more universal than any of the others previously mentioned. This technique has been used to estimate population size for whales, coyotes, bears, and marten. Because scat collection for wolverine is unlikely to be feasible (see Method 9), a DNA based inventory for wolverine is likely to follow a design similar to that used for bears and marten (Woods et al. 1999, Mowat and Strobeck 2000, Mowat and Paetkau 2002)

Assumptions: 1) The most important assumption for wolverine may be the assumption of population closure, which White et al. (1982) term geographic closure. Essentially this assumption means that the ratio of marked to unmarked animals does not change between sessions. This assumption is violated if there is significant movement of individuals on and off the study area between trapping sessions. This assumption is minimized by selecting study area boundaries that physically enclose animals on the study area. A significant positive bias can result if many animals are only partial residents. This problem is minimized when average home range size is small compared to the size of the study area (White et al. 1982). 2) no gross variation in capture rates, especially combining heterogeneity, time, and behavioural response.

Limitations: 1) capture rate at hair stations may be limiting, 2) genetic analysis can be expensive if large numbers of samples are collected.

Benefits: 1) can be done over large areas, 2) provides an estimate of precision, 3) cost effective, though there may be certain one time developmental costs required for the genetic analysis, 4) the method is nonintrusive.

Radio isotope marking and recapture of scats involves live capturing a sample of wolverine, injecting them with a radio isotope, and calculating marked to unmarked ratios from a scat collection program subsequent to the marking session (Conner and Labisky 1985). Scats from marked individuals are identified by their mild radioactivity using a Geiger counter. This technique is not likely to work for wolverine because collecting and positively identifying a large sample of scats would be virtually impossible. Confident scat identification is probably only possible by following tracks in winter or genetic analysis. The effort required to collect >100 scats would be enormous. Less expensive and probably satisfactory results could be obtained using method 2 in this case.

Assumptions: 1) The most important assumption for wolverine may be the assumption of population closure, which White et al. (1982) term geographic closure. Essentially this assumption means that the ratio of marked to unmarked animals does not change between sessions. This assumption is violated if there is significant movement of individuals on and off the study area between trapping sessions. This assumption is minimized by selecting study area boundaries that physically enclose animals on the study area. A significant positive bias can result if many animals are only partial residents. This problem is minimized when average home range size is small compared to the size of the study area (White et al. 1982). 2) All animals have equal catchability. This is virtually impossible however, Miller et al. (1997) felt that this bias was minimal because they marked bears over multiple years and used a different recapture technique. 3) Individuals must be positively identified using DNA analysis.

Limitations: 1) Requires a live captured sample of wolverine, 2) capture rate of scats may be limiting, 3) politically sensitive due to the use of radioactive marker.

Benefits: 1) Can be done over large areas, 2) provides an estimate of precision.

Radio isotope marking and recapture using hunter or trapper samples. Garshelis and Visser (1997) marked a sample of bears using baits laced with tetracycline. They recaptured bears using hunter submissions and examined teeth and ribs to confirm previous marking and then used a Lincoln-Petersen model to estimate population size. You must be able to determine how many different animals ate baits and were marked during the marking session. Garshelis and Visser (1997) did this by using small baits that were entirely consumed by one individual and confirming the individual was a bear by tracks and claw marks in trees. This method would only work for species which are harvested in substantial numbers which is not the case for wolverines.

Assumptions: 1) The most important assumption for wolverine may be the assumption of population closure, which White et al. (1982) term geographic closure. Essentially this assumption means that the ratio of marked to unmarked animals does not change between sessions. This assumption is violated if there is significant movement of individuals on and off the study area between trapping sessions. This assumption is minimized by selecting study area boundaries that physically enclose animals on the study area. A significant positive bias can result if many animals are only partial residents. This problem is minimized when average home range size is small compared to the size of the study area (White et al. 1982). 2) All animals have equal catchability. This is virtually impossible however, this bias may minimal because individuals are marked and recaptured using different techniques.

Limitations: 1) You must be able to confirm how many individuals are marked during baiting, 2) the recapture rate may be limiting because wolverine harvest is relatively small and scattered, 3) politically sensitive due to the use of radioactive marker.

Benefits: 1) Can be done over large areas, 2) provides an estimate of precision.

5.0 DISCUSSION

There are several realistic methods for estimating wolverine abundance across large areas of Alberta. Radio telemetry and snow tracking are not likely to be useful because of the high cost and the fact only small areas can be studied. Aerial track sightability methods have many advantages but forests are likely to be too closed to achieve adequate sighting probabilities; there is a small chance the method might work in the far north of the province. Becker's (1991) methods could be used with snow tracking on the ground but this would involve a massive logistic effort over a very short time frame (1-3 days) when snow conditions were good. Live capture methods are likely to be too expensive and it would be difficult to mark reasonable numbers of individuals. Radio isotope marking and trapper returns could theoretically work but again sample sizes are likely to be small given the relatively low harvest of wolverine in Alberta (average of 30 animals/year over the last decade). Further, radio isotope marking can meet significant opposition with the public and is therefore a politically difficult method to employ.

This leaves DNA based method or track counts to detect and potentially identify wolverines. Track counts could be a cost-effective method to detect and monitor wolverine distribution. Population estimates are not possible with track counts but they can be used to measure relative abundance. However, track counts can be difficult to standardize and carry out due to variation in snow conditions and animal movement patterns among areas. Scat sampling is logistically simple for many species but is unlikely to be efficient for wolverine because their scats are difficult to find, relatively rare in the environment, and easily confused with those of other similar sized carnivores. This size overlap necessitates genetic species testing for large numbers of non-target species to acquire many fewer target samples. Hair sampling of wolverine appears to be the most likely route to success at this time. Three methods have been used to remove hair noninvasively from terrestrial carnivores: 1) glue patches in baited traps (Foran et al. 1997a), 2) rub pads on trees (McDaniel et al. 2000), 3) and barbed wire bait sites (Woods et al. 1999).

Glue patches have been tested on captive wolverine (D. Lewis and D. Fear, unpubl. Data), and on wild wolverines in 2 study areas in British Columbia (J. Krebs, Columbia Basin Fish and Wildlife Compensation Program, pers. com., & E. Lofroth, BC Ministry of Environment, Lands and Parks, pers. com.). Hair samples have been collected using glue patches but results have been inconsistent; this is likely because wolverines have very coarse deeply rooted hair. Also baited glue patches are often contaminated by other more abundant species such as marten. This combined with the fact that the glue is no longer sticky below about –20°C makes glue based methods undesirable for broad use. Also, glue samples require special treatment in the lab to remove hair from the glue which would increase the cost of analysis.

Rub pads, as applied for lynx, have never been known to sample hair from wolverines (J. Copeland, pers. com). Wolverines are known to rub on many objects and odours so it is possible that a rub type method could be developed for wolverine. Jeff Copeland and colleagues will be working on this possibility over the next year or so. This method will probably require considerable work testing various odours and hair grabbing mechanisms on captive wolverine.

Baited barbed wire sites are probably the simplest route for collecting DNA samples from free ranging wolverines in northern Canada. Sampling in winter would avoid conflict with bears but if non-rewarding sites are established working in the winter may not be a necessity. For example, baits can be hung in trees in summer to avoid rewarding bears (Woods et al. 1999). I believe we have removed hair samples from wolverine occasionally during bear inventory work, however we have never confirmed this using a genetic test. Bear bait sites have incidentally removed hair from wolves in northern BC (Poole et al. 2001). The project leaders of both current wolverine research projects in British Columbia suggested that they had the most consistent success removing wolverine hair using barbed wire at variously configured bait sites (J. Krebs, & E. Lofroth). Two successful methods described by these biologists involve bait sites circled by several strands of barbed wire or, baited cubbies with several strands of barbed wire spaced across the mouth.

Many hair samples collected in the above kinds of sites can be confirmed as wolverine by tracks at the site or, macroscopic or microscopic examination of hair. Samples which are in doubt can be tested using a genetic test. Several genetic tests have been developed for forest carnivores (Foran et al. 1997b, L. Scott Mills, unpubl. data) but neither test can be used on an automated sequencer. This means the test is not commercially efficient or cost effective. David Paetkau (Wildlife Genetics International, unpubl. data) has developed an automated test for felids and canids which could be expanded to mustelids with modest effort. Additionally, some testing of microsatellite markers should be done in order to propose a suite of markers which work efficiently with small volume DNA samples typical of hair samples. And, to select markers which have enough variation to identify individuals with adequate degree of certainty (Paetkau et al. 1998, Woods et al. 1999).

5.1 Workplan for Estimating Density or Trend for Wolverine in Northern Alberta

1. I suggest testing two hair-grabbing systems for wolverine during winter 2000-2001 in northern Alberta. Every effort should be made to maximize the number of sites sampled because we will only be learning something about the hair sampling mechanisms when a wolverine approaches a site which is a relatively rare event. I suggest using a bait site surrounded by barbed wires spaced 30 cm apart. Enclosures do not need to be large, a diameter of 3 m or larger should suffice. Large meat baits could be hung from trees, attached to a tree, or put in a secure container such as an ammunition box in the centre of the site. Wires can be stapled to trees, three or more strands of wire may be needed if snow

accumulations are likely to be significant during the two weeks the site is to active. A second system could be prefabricated of half-inch plywood. A box 3 feet long box, 2 feet wide and high, which is closed at one end, could be carried on a snowmobile or in a helicopter. This box could be quickly tacked together with a hammer and bait put in the back. Then a single strand of barbed wire could be strung back and forth across the mouth of the box leaving 20-30 cm openings in which a wolverine could pass thru, while hopefully leaving a hair sample.

2. Collect tissue samples from all wolverine killed on each area sampled this winter. Trapper samples from around each hair sampling area would also be useful for getting an idea of recapture probabilities, movements, and closure. Tissue samples would also be useful for developing the species test and testing microsatellite markers.
3. Collect all suspected wolverine scats that field crews encounter this winter. All scats should be stored as soon as possible in 90-100% ethanol. It is not necessary to collect entire scats. A volume as small as a teaspoon may be sufficient for analysis though a tablespoon or more is preferable. These scats would be useful for testing scat extractions for wolverine. Individuals identified via scat could also be used in cumulative catch modelling.
4. Sampling this first winter need not follow a strong study design; the effort should be to put out as many sites as possible to test the efficiency of each trap system, improve the devices, and get a reasonable idea of capture success to aid in study design during subsequent years.
5. Sampling is likely to be most effective in late February or March when warmer weather is likely to encourage greater movement and hence increase detection rates. Trapping in April will overlap with the denning season and female detection rates may decline during this period. However, denning females are a small component of the population and once the kits are more than a few days old even denning females make significant movements (J. Krebs & E. Lofroth, pers. comm.). The reduction in capture probabilities caused by denning may be small.
6. Use strong smelling lures and baits; put baits in inaccessible containers such as ammunition boxes to avoid rewarding individuals and to increase the longevity of the bait. Rotten meat of any description should work as bait. I suggest a mixture of fish oil and beaver castor poured over cotton balls in film containers as lure. The film containers can be prepared ahead of time and closed for ease of travelling and then nailed to the bait tree, as high up as possible, so the scent is captured by air movement.
7. Traps can be set and left for 7-14 days. Try to remove hair samples after about 14 days as DNA does degrade the longer it is in the field. Store samples in paper envelopes in a dry place out of the sun. Use a lighter to clean off barbs which have residual hair stuck on them. Hair can be removed from barbed wire with bare hands. Detailed notes, including photos, should be taken regarding any evidence of which species visited a given site. Sites should be spaced far enough apart to have a reasonable chance of detecting a different wolverine. Five to 10 km spacing should be reasonable.
8. I suggest effort be put into developing a commercially viable species test for wolverine and other similar species to support the prototype testing this year. All

labs currently studying forest carnivores in the US have chosen to use restriction enzyme tests. These tests are cheap to employ and effective but they require considerable labour time. These methods are most suitable in academic settings where labour is relatively inexpensive and capital budgets are often limited. It is generally better to automate as much of the procedure as possible for commercial application to save costs. All genetic tests for grizzly bear inventories use an automated sequencer which reduces costs and decreases the turn around time in the lab. It is worthwhile to develop this capacity for wolverine and other mustelids such as fisher and otter. An automated species test is already available for lynx (D. Paetkau, pers com.). If an automated test proved intractable several restriction methods are available, or soon will be, that could serve the same purpose (Foran et al. 1997b, L. Scott Mills, upubl. data).

9. Regular communication with Jeff Copeland and others with interests in developing a hair capture method for wolverine is necessary to compare other options, and perhaps co-operate with testing. Efforts by US biologists will serve as the back-up plan should the above barbed wire methods turn out to be ineffective.
10. Chris Kyle is a Ph.D. candidate with Curtis Strobeck at the University of Alberta. He is studying the genetic structure of wolverine and other mustelids across their North American range (Kyle and Strobeck, In Press). He would like to include any hair samples collected during this work in his analysis. Apart from the obvious applications of his analysis, it may be useful to have him analyze all the wolverine samples collected in the first year because he will run the samples at many more microsatellite loci than needed for inventory purposes. His results could then be used to select a smaller suite of markers that perform well with hair samples and across the range of wolverine distribution in Alberta. In essence, Chris' data could be used to select an optimal suite of markers for wolverine identification in Alberta.

5.2 Long-term Workplan for Developing a Wolverine Population Inventory Method

If effective hair sampling and species testing methods can be developed for wolverine the next step would be to assess the goals of wolverine inventory. The most important question is what to monitor? The simplest parameter to monitor is distribution; changes in wolverine distribution can then be used to infer changes in wolverine population size. Distribution can be measured with systematic snow tracking or hair sampling data. Alternatively, an index of population size could be derived which could be compared among years to infer changes in population size; the two most common indices in this context are the proportion of sites that detect wolverine per given area or, the number of detections per trapnight. A third possible index is the number of individuals detected in a given survey; however, this index requires genotyping all hair samples. However, it may be useful to estimate population size even when monitoring is the goal because population indices, such as that proposed above, are often biased (Lancia et al. 1994). Using the proportion of sites that detect wolverine as an index of abundance assumes that the mean capture probability was similar among sampling periods, which is unlikely.

Hunting, live-capture, weather, baits and even previous bouts of hair sampling may change capture probabilities and generate misleading results. It may be better to design a monitoring strategy that would allow the estimation of population size, even if sample sizes are likely to be low. Interestingly, each of the above goals can be measured with similar study designs. Low precision may be acceptable if the objective is to monitor abundance and deduce population trend and surveys are done regularly and analysed as a time series. Even somewhat arbitrary designs can be used to estimate population size in cumulative catch models such as that presented by Minta and Mangel (1989) and Boyce et al. (In Press). Cumulative catch models may give accurate results for inventories where capture effort is not organized into sessions if samples were genotyped, for example when sampling is done over one prolonged period, which is the case for many presence-absence surveys. A series of these point estimates can then be investigated, along with the accompanying variances, for signs of population change. A survey originally designed to generate a minimum number of individuals could also be used to estimate population size using mark-recapture if trapping effort is divided into discreet sessions.

I suggest the following steps to test several methods of population inventory. Stan Boutin and colleagues will be using a systematic sampling method over large areas (≈10,000 km^2) in order to measure wolverine distribution. They will sample each cell only once and they will sample new cells continually through the late winter sampling period. They will sample each cell using a 9 km track transect and a bait site as described earlier in this paper. In its simplest form their data could be used to infer changes in distribution however, depending on sampling intensity and the size of their study area, their data may be able to be used to estimate population size. I suggest that Alberta NRS genotype all wolverine hair samples collected by Dr. Boutin's crew in order to get an idea of how many individual wolverine are captured per given area. This information may help in future study designs. If samples were adequate, it would be worthwhile to attempt to estimate population size using a cumulative catch estimator.

Secondly, I suggest Alberta NRS select a study area and employ a mark-recapture study design based on study recommendations in this paper. It would make sense to begin with an area of high population density and good ground access to reduce costs. Results from this study could then be used to predict capture rates, precision, and accuracy of the method. The precision could then be used in power analysis to predict the ability to detect population declines under several scenarios. Several good papers exist which would allow general predictions without any simulation work (Gerrodette 1987, Zeilinski and Hauffer 1996, Strayer 1999). The costs and outcomes of such a study could be compared with detection studies to help decide on a long-term action plan.

We can construct a scenario for a wolverine mark-recapture survey using observations from previous work and the results simulations done for designing grizzly bear inventories (Mowat, Unpubl. data). Table 1 would suggest that wolverine density in northwest Alberta might be 3-5 individuals/1000 km^2. This means selecting a study area of 12-20,000km^2 in order to encircle a population of 60 or more animals. If we set our objective for precision at ≤30% of the estimate when alpha = 0.05 then we must capture about 25% of the population in each of 4 trapping sessions; 15 animals if the population size is 60 (Mowat, Unpubl. data). Previous trapping experience suggests that we can expect to catch about one animal per 75 trap-nights (see Table 1). If we use 14 day tapping sessions we need to set 75 sites to catch about 16 animals per session based on an average of 75 trapnights/capture. Alternatively, we could set 50 sites for 21 day sessions and achieve the same capture success. In reality, longer sessions won't necessarily achieve greater capture success because the bait or lure will lose effectiveness and the site may be rendered inoperable by snow or disturbance and, it will remain in this condition longer with a longer session. And, longer capture sessions increase the length of the study, which may increase closure bias and necessitate working during periods when capture success is likely to be lower, such as early February.

Cells would have to be 400 km^2 or smaller to achieve the above trap density. We also need to select cell sizes that give all individuals-females are the important cohort in this respect-at least a small chance of being captured. If the capture probability is zero for an individual then mark-recapture models will underestimate population size by the number of individuals that have zero capture probabilities (K. Pollock, pers. comm.). Given the large home ranges of wolverine (Banci 1994), cell sizes of 400 km^2 are unlikely to result in zero capture probabilities for any individuals, especially if sites are put in the most attractive location in a cell, moved for each trapping session, and there are 4 or more sessions. This may not be true during the denning season when some females have much smaller home ranges (Banci 1994). If funding permits, it would be best to have fairly intensive sampling for the first mark-recapture inventory in order to maximize the capture probability of breeding females. Sixty cells in a high density area of 12-15,000 km^2 study area would be a logical first design. Capture results from the first winter of trap testing could be used to refine this design somewhat.

5.3 Risks

There are a number of aspects, which make the development of an inventory technique for wolverine uncertain. The following is a list of things that may not work out and some suggestions as to how to deal with the problem.

Neither barbed wire method works effectively for removing useful hair samples from wolverine.

- Refine the methods and test further prototypes in subsequent years.
- Consider using methods being developed by American biologists.

We cannot develop an automated species test.

- Use the restriction enzyme tests used in the US.
- Many species can be separated macro- or microscopically.
- There is a very small chance of this aspect failing as it has been used for many other carnivores.

Microsatellites are not powerful enough to identify individuals.

- This is very unlikely as there are quite a number of microsatellites, which work on wolverine, and many of these have been tested on Alberta wolverine (Davis and Strobeck 1998, Kyle and Strobeck, In Press).

- More microsatellites could be developed specifically for wolverine. This would cost between $5000 and $15,000.

Sample sizes or budgets are too small to use mark-recapture models.

- Use cumulative catch models if possible.
- Measure distribution or relative indices of abundance.

5.4 Fisher, Lynx, and Otter Inventory Methods

Both barbed wire traps proposed may detect fisher or lynx. Neither trap is likely to detect otter with any regularity. Fisher are probably most likely to be detected in the cubby set while the reverse is probably true for lynx. Given the small size of fisher and the great care that cats take in their movements it seems unlikely that either trap will be highly effective for fisher or lynx. Non-invasive methods have been developed that are likely to work for both species. Rub pads were developed by John Weaver of Wildlife Conservation Society and have been tested in the Yukon (McDaniel et al. 2000) and in many parts of the lower 48 states (S. L. Scott Mills, unpubl. data). They appear to be effective at detecting lynx and bobcat. These devices are simple and can be used in summer or winter. Stan Boutin of the University of Alberta will be testing this method in northeast Alberta during winter 2000-2001.

Non-invasive methods have not been developed for fisher but methods exist for marten using glue patches (Foran et al. 1997a, Mowat and Paetkau 2002) and it seems likely that they would work for fisher. E. Lofroth and associates (unpubl. data) detected fisher when testing glue patches for wolverine in northern British Columbia. The size of the trap may have to be increased for fisher over that of marten. Other inventory options exist for both species and may be worth examining.

No non-invasive sampling has been done for otter though scats are easily identifiable and could be used as a source of DNA. Developing other methods for sampling otter DNA could prove difficult. Counts of otter sign along waterways have been used in the United Kingdom as a means of indexing otter abundance; the usefulness of this method to estimate population size is in debate (Kruuk and Conroy 1987, Mason and Macdonald 1987). Reid et al. (1987) present a method for estimating otter abundance using sign which may be useful for broad scale inventories. It is unlikely that otters can be surveyed at the same time as other furbearers because their specialized habitat use will require sampling along waterbodies.

6.0 LITERATURE CITED

Banci, V. 1987. Ecology and behaviour of wolverine in Yukon. M.Sc. Thesis, Simon Fraser University, Vancouver, B. C.

Banci, V. 1994. Wolverine. Pages 99-127 *in* L. F. Ruggerio, K. B. Aubry, S. W. Buskirk, L. J. Lyon, and W. J. Zielinski eds. The scientific basis for conserving forest carnivores: American marten, fisher, lynx, and wolverine in the western United States. USDA Forest Service GTR RM-254.

Banci, V. A. and A. S. Harestad. 1990. Home range and habitat use of wolverines in Yukon, Canada. Holarct. Ecol. 13:195-200.

Becker, E. F. 1991. A terrestrial furbearer estimator based on probability sampling. J. Wildl. Mange. 55:730-737.

Becker, E. F., M. A. Spindler, and T. O. Osborne. 1998. A population estimator based on network sampling of tracks in the snow. Journal of Wildlife Management 62:968-977.

Bondrup-Neilsen, S. 1983. Density estimation as a function of live-trapping grid and home range size. Can. J. Zool. 61:2361-2365.

Boutin, S. 1984. Home range size and methods of estimating snowshoe hare densities. Acta. Zool. Fennica, 171:275-278.

Boyce, M. S., Mackenzie, D. I., Manly, B. F. J., Haroldson, M. A., and Moody, D. 2000. Negative binomial models for counts of unique individuals. J. Wildl. Mange. In Press.

Conner, M. C. and R. F. Labisky. 1985. Evaluation of radioisotope tagging for estimating abundance of raccoon populations. J. Wildl. Mange. 49:326-332.

Copeland, J. 1993. Assessment of snow-tracking and remote camera systems to document presence of wolverine at carrion bait stations. Unpublished report. Idaho Dept. of Fish and Game.

Copeland, J. 1995. Biology of the wolverine in central Idaho. M.Sc. Thesis, University of Idaho, USA.

Davis, C., and C. Strobeck. 1998. Isolation, variability, and cross-species amplification of polymorphic microsatellite loci in the family Mustelidae. Molecular Ecology **7**:1776-1778.

Foran, D. S., S. C. Minta, and K. S. Heinemeyer. 1997a. Species identification from scat: an unambiguous genetic method. Wildlife Society Bulletin 25:835-840.

Foran, D. S., K. C. Crooks, and S. C. Minta. 1997b. DNA-based analysis of hair to identify species and individuals for population research and monitoring. Wildlife Society Bulletin 25:840-847.

Garshelis 1992. Estimating bear population size. Pages 1098-1111 *in* D. R. McCullough and R. H. Barrett. Editors. Wildlife 2001:Populations. Elsevier Applied Science, London.

Garshelis, D. L. and L. G. Visser. 1997. Enumerating megapopulations of wild bears with an ingested biomarker. J. Wildl. Mange. 61:466-480.

Gerrodette, T. 1987. A power analysis for detecting trends. Ecology 68: 1364-1372.

Haglund, B. 1966. Winter habits of the lynx and wolverine as revealed by tracking in the snow. Viltrevy 4:81-299.

Hallet, J. G., M.A. O'Connell, G.D. Saunders, and J. Seidensticker. 1991. Comparison of population estimators for medium-sized animals. J. Wildl. Mange. 55:81-93.

Hornocker, M. G. and H. S. Hash. 1981. Ecology of wolverine in northwestern Montana. Can. J. Zool. 59:1286-1301.

Jolly, G. M. and J. M. Dickson. 1983. The problem of unequal catchability in mark-recapture estimation of small mammal populations. Canadian Journal of Zoology 61:922-927.

Krebs, C. J. 1989. Ecological Methodology. Harper and Row, New York.

Krebs, J. and D. Lewis. Progress report on Revelstoke wolverine study. 2000. In: L. Darling, editor. Biology and management of species and habitats at risk; proceedings of Kamloops conference. B.C. Ministry of Environment, Lands and Parks, Victoria.

Kruuk, H. and J. W. H. Conroy. 1987. Surveying otter populations: a discussion of problems with spraints. Biological Conservation 41:179-183.

Kyle, C. J. and C. Strobeck. In Press. Genetic structure of North American wolverine populations. Molecular Ecology.

Lancia, R. A., J. A. Nichols, and K. H. Pollock. 1994. Estimating the number of animals in wildlife populations. Pages 215-253 *in* T. A. Bookout, editor. Research and management techniques for wildlife and habitats. Fifth Edition, The Wildlife Society, Bethesda, Maryland.

Landa, A., R. Franzen, T. B. J. Tufto, M. Linden and J. E. Swenson. 1998. Wolverines in Scandinavia: population size and distribution in 1996. Wildlife Biology 4:159-168.

Mace, R. D., S. C. Minta, T. L. Manley, K. E. Aune. 1994. Estimating grizzly bear populations size using camera sightings. Wild. Soc. Bull. 22:74-83.

Magoun, A. J. 1985. Population characteristics, ecology, and management of wolverines in northwestern Alaska. PhD. Thesis, Univ. Alaska, Fairbanks.

Mason, C. F. and S. M. Macdonald. 1987. The use of spraints for surveying otter populations: an evaluation. Biological Conservation 41:167-177.

McCullough and D. H. Hirth. 1988. Evaluation of the Petersen-Lincoln estimator for a white-tailed deer population. J. Wildl. Mange. 52:534-544.

McDaniel, G. W., K. S. McKelvey, J. R. Squires, and L. F. Ruggiero. 2000. Efficacy of lures and hair snares to detect lynx. Wildlife Society Bulletin 28:119-123.

Miller, S. D. et al. 1997. Brown and black bear density estimation in Alaska using radiotelemetry and replicated mark-resight techniques. Wildl. Mono. 133.

Minta, S. and Mangel, M.. 1989. A simple population estimate based on simulation for capture-recapture and capture-resight data. Ecology 70: 1738-1751.

Mowat, G. 1997. Problem Analysis-Estimating Wolverine Population Size. Final Report for Columbia Basin Fish and Wildlife Compensation Propram, Nelson, BC, Canada.

Mowat, G., and Strobeck, C. 2000. Estimating population size of grizzly bears using hair capture, DNA profiling, and mark-recapture analysis. J. Wildl. Mange. 64: 183-193.

Mowat, G. and D. Paetkau. 2002. Estimating marten population size using hair capture and genetic tagging in southeast British Columbia. Wildlife Biology 8:201-209.

Otis, D. L., K. P. Burnham, G. C. White, and D. P. Andersen. 1978. Statistical inference from capture data on closed animal populations. Wildl. Mono. 62.

Paetkau, D. W., L. Waits, P. L. Clarkson, L. Craighead, E. Vyse, R. Ward, and C. Strobeck. 1998. Variation in genetic diversity across the range of North American brown bears. Conservation Biology 12:418-429.

Petersen, S. 1997. Status of wolverine in Alberta. Alberta Environmental Protection, Wildlife Management Division, Wildlife Status Report No. 2, Edmonton, Alberta.

Poole, K. G., Mowat, G., and D. A. Fear. 2001. DNA-based population estimate for grizzly bears in northeastern British Columbia, Canada. Wildlife Biology, In Press.

Pollock, K. H., J. D. Nichols, C. Brownie, and J. E. Hines. 1990. Statistical inference for capture-recapture experiments. Wildl. Mono. 107.

Pulliainen, E. 1963. Occurrence and habits of the wolverine in Finland. Suomen Riista 16:109-119.

Quick, H. F. 1953. Wolverine, fisher, and marten studies in a wilderness region. Trans. N. Amer. Wildl. Conf. 18:513-532.

Reid, D. G., M. B. Bayer, T. E. Code, and B. McLean, 1987. A possible method for estimating river otter populations using snow tracks. Canadian Field Naturalist 101:576-580.

Rexstad, E. and K. Burnham. 1991. User's guide for interactive program CAPTURE.

Ruggiero, L. et al. editors. The scientific basis for lynx conservation. USFS General Technical Report, RMRS-GTR-30WWW and The University Press of Colorado.

Strayer, D. L. 1999. Statistical power of presence-absence data to detect population declines. Conservation Biology 13:1034-1038.

Thompson, I. D., I. J. Davidson, S. O'Donnell, and F. Brazeau. 1989. Use of track transects to measure the relative occurrence of some boreal mammals in uncut forest and regeneration stands. Canadian Journal of Zoology 67:1816-1823.

White, G. C., D. R. Andersen, K. P. Burnham, D. L. Otis. 1982. Capture-recapture and removal methods for sampling closed populations. Los Alamos Nat. Laboratory LA-8787-NERP.

Woods, J. G., Paetkau, D., Lewis, D., McLellan, B. N., Proctor, M., and Strobeck, C.. 1999. Genetic tagging free ranging black and brown bears. Wildl. Soc. Bull. **27**: 616-627.

Zielinski, W. J., and H. B. Stauffer. 1996. Monitoring *Martes* populations in California: survey design and power analysis. Ecological Applications 6:1254-1267.

7.0 BIBLIOGRAPHY

Butts, T. W. 1992. Wolverine biology and management: a literature review and annotated bibliography. Unpubl. Report. USDA-USFS, Northern Region.

Hash, H. S. 1987. Wolverine. Pages 574-585 *in* M. Novak, J. A. Baker, M. E. Obbard, B. Malloch, eds. Wild furbearer conservation and management in North America. Ontario Ministry of Natural Resources, Ontario.

Pasitschniak-Arts, M. and S. Lariviere. 1995. Gulo gulo. Mammalian Species No. 499.

Zielinski, W. J. and T. E. Kucera. 1995. American marten, fisher, lynx and wolverine: survey methods for their detection. USDA Forest Service GTR-157.

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